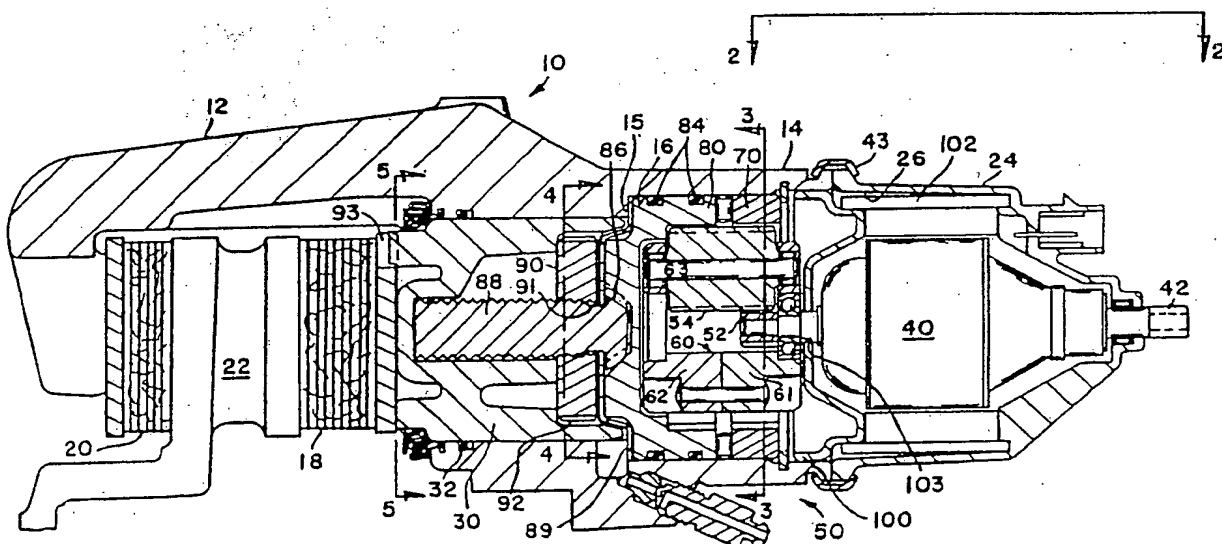


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US87/02348 <b>(22) International Filing Date:</b> 15 September 1987 (15.09.87)  <b>(31) Priority Application Number:</b> 946,400 <b>(32) Priority Date:</b> 23 December 1986 (23.12.86) <b>(33) Priority Country:</b> US  <b>(71) Applicant:</b> ALLIED CORPORATION [US/US]; Law Department (F.M. Leather), P.O. Box 2245-R, Morristown, NJ 07960 (US).  <b>(72) Inventors:</b> TAIG, Alistair, Gordon ; 19032 Sommers Drive, South Bend, IN 46637 (US). GRABILL, Paul, Joseph ; 54739 Winding Brook Drive, Mishawaka, IN 46545 (US). JACKSON, Robert, William ; 17450 Fairlane Drive, South Bend, IN 46635 (US).		<b>(74) Agent:</b> WINTER, Richard, C.; Allied Corporation, Law Department (F.M. Leather), P.O. Box 2245-R, Morristown, NJ 07960 (US).  <b>(81) Designated States:</b> AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), FR (European patent), GB (European patent), HU, IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent).  <b>Published</b> <i>With international search report.</i>

**(54) Title:** ELECTRICALLY OPERATED DISC BRAKE**(57) Abstract**

The electrically operated disc brake (10, 110, 310, 410) may be operated by either hydraulic pressure and an electric motor or operated solely by means of an electric motor. The electric motor (40, 340, 440) drives a sun gear (52, 352, 452) of a planetary gear assembly (50, 150, 350, 450). The planetary gear assembly (50, 150, 350, 450) includes a fixed ring gear (70, 370, 470) and a rotatable ring gear (80, 180, 380, 480), the rotatable ring gear (80, 180, 380, 480) having fewer teeth than the fixed ring gear (70, 370, 470) so that rotation of the planetary gears (54, 56, 58) effects a slower rate or rotation of the rotatable ring gear (80, 180, 380, 480). The rotatable ring gear (80, 180, 380, 480) engages a screw (88, 188, 388, 488) which is connected with the piston (30, 130, 330, 430). The piston (30, 330, 430) may be displaced by hydraulic fluid for a service application and the electric motor (40, 340, 440) utilized for a parking application. Alternatively, the piston (130) may be displaced by the electric motor (40) for both service and parking brake applications.

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## ELECTRICALLY OPERATED DISC BRAKE

This invention relates generally to a disc brake that may be operated both hydraulically and electrically, or solely by motor means.

5           Disc brakes have been utilized for many years in passenger cars, heavy duty trucks, and aircraft. Because of the increasing emphasis on reducing the weight of vehicles and simplifying the components thereof, it is desirable to develop a braking system that is operated  
10 electrically. Such a braking system must be highly reliable, cost effective, and practical within the packaging constraints of the particular vehicle. The present invention provides a disc brake that may be operated either solely by means of an electrically or hydraulically oper-  
15 ated motor or be operated hydraulically for a service brake application and operated by the motor for a parking brake application. The result is a highly reliable, low cost, electrically operated disc brake which will fit readily within the packaging constraints of several  
20 vehicles.

The present invention comprises a disc brake that may be operated by motor means, comprising a caliper having a bore with a piston slidably received therein, the caliper and piston actuatable to displace a pair of  
25 friction elements into engagement with a rotor, a planetary gear assembly disposed within said bore and comprising a sun gear, planetary gears, and a pair of ring gears, and the motor means coupled with said sun gear which drives the planetary gears, one ring gear fixed to  
30 said caliper and the other ring gear rotatable by said planetary gears, the other ring gear engaging screw means which is connected with said piston, operation of said motor means causing rotation of said other ring gear and operative displacement of said piston into engagement  
35 with one of said friction elements so that the caliper, by reaction, displaces the other friction element into engagement with said rotor.

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The invention is described in detail below with reference to the drawings which illustrate embodiments in which:

5 Figure 1 is a section view of the first embodiment;

Figure 2 is a partial section view along view line 2-2 of Figure 1;

Figure 3 is a section view along view line 3-3 of Figure 1;

10 Figure 4 is a section view along view line 4-4 of Figure 1;

Figure 5 is a section view along view line 5-5 of Figure 1;

15 Figure 6 is a section view of a second embodiment of an electrically operated disc brake;

Figure 7 is an alternative embodiment of the brake of Figure 6;

Figure 8 is an end view of a duplex support plate and disc brake;

20 Figure 9 is a section view of a twin bore disc brake;

Figure 10 is a section view taken along view line 10-10 of Figure 9;

25 Figure 11 is an end view of the brake of Figure 9;

Figure 12 is a section view of a twin bore disc brake; and

Figure 13 is an end view of the brake of Figure 12.

30 The disc brake of the present invention is referenced generally by numeral 10 in Figure 1. Disc brake 10 comprises a brake that is operated by either hydraulic pressure or an electric motor. Disc brake 10 includes a caliper 12 having a caliper housing 14 with a  
35 bore 16. Caliper 12 extends over a pair of friction elements 18 and 20 which may be displaced toward one another in order to brake a rotor 22. The bore 16 comprises a stepped bore having a piston 30 slidably dis-

- 3 -

posed therein, the piston having a seal 32 located there-  
about in order to prevent hydraulic fluid from exiting  
bore 16. Caliper housing 14 is connected with an elec-  
tric motor housing 24 which has a bore 26 housing an  
5 electric motor 40. Motor 40 may comprise other types of  
motors, such as an hydraulic motor. Housing 24 is coupled  
to caliper housing 14 by means of a clamp band 43, the  
clamp band 43 held together by a nut and bolt connection  
44 (see Figure 2). A planetary gear assembly 50 is dis-  
10 posed within bore 16, the planetary gear assembly 50  
comprising a sun gear 52, three planetary gears 54, 56,  
and 58 (see Figure 3), a two-part carrier 60 comprising  
carrier parts 61 and 62, pins 63 which carry the plane-  
tary gears, and two ring gears 70 and 80. Each ring gear  
15 has internal teeth, and ring gear 80 is rotatable but has  
fewer teeth than ring gear 70 which is fixed to caliper  
housing 14. Rotatable ring gear 80 includes thereabout a  
pair of seals 84, the seals preventing hydraulic fluid  
from entering into the planetary gear assembly. Rotatable  
20 ring gear 80 is coupled nonrotatably through a tapered  
spline connection 86 with screw means 88. Screw means 88  
has external threads engaging the threads of nut 90, and  
is supported in opening 31 of piston 30 (see Figures 1  
and 5). Nut 90 is coupled nonrotatably through a key  
25 connection 92 (see Figure 4) with piston 30. Piston 30  
is coupled nonrotatably by means of connection 93 with  
friction element 18. Disposed about screw means 88 is a  
screw-retaining plate 89 which is held in axial position  
between housing shoulder 15 and rotatable ring gear 80,  
30 the retaining plate 89 having a central opening 91 for  
screw means 88. Fixedly positioned retaining plate 89  
prevents screw means 88 from moving axially within bore  
16. Located at the other end of bore 16 is a motor plate  
100 that encloses the end of bore 16 and also engages the  
35 steel ring 102 of motor 40. Plate 100 has an opening 103  
which effects alignment of the drive shaft of motor 40,  
and the plate also extends within steel ring 102 in order  
to position the motor. Steel plate 100 keeps gearbox oil  
from entering into bore 26 and motor 40.

The planetary gear assembly has a high reduction ratio which is achieved by having fewer internal teeth on rotatable ring gear 80 than on fixed ring gear 70. Sun gear 52 causes planet carrier 60 to rotate in the same direction as the sun gear, but at a reduced speed due to the fixed ring gear 70. The two ring gears 70 and 80 have different numbers of teeth, the difference being equal to the number of planetary gears, (normally two or three). Thus, as planet carrier 60 rotates, the planetary gear teeth engage with the adjacent teeth of the two ring gears 70 and 80, and for each rotation of the planet carrier 60, rotatable ring gear 80 advances by three teeth (for a design with three planetary gears) or two teeth (for a design with two planetary gears). Hence, the overall ratio of the gear train is the ratio of speed of the sun gear to the planet carrier multiplied by the number of teeth of the output rotatable ring gear divided by the number of planetary gears. A typical system might have 18 teeth on the sun; 72 teeth on the fixed ring; 69 teeth on the output rotatable ring, and three planetary gears. The overall ratio would be:

$$\left(\frac{72}{18}+1\right) \times \frac{69}{3} = 115/1$$

The difference in tooth numbers is achieved by modifying the operating pressure angles of the internal teeth so that the gear with fewer teeth (preferably the rotatable ring gear 80) engages at a higher pressure angle than that with more teeth. The high pressure angle teeth can be generated with a standard 20° involute cutter working on an enlarged internal gear blank at the appropriate ratio.

The screw means 88 can have a friction reducing surface treatment in order to improve drive efficiency. However, for parking brake use it is essential to choose a drive screw which is irreversible so that the brake remains applied after the motor current is turned off. A reverse motor torque is used to release the brake.

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A motor control circuit which controls motor torque (or current) is used. In a parking brake application, a hand lever with force feedback can be used to control a variable sensor such as a rheostat or force transducer which signals the controller to provide the appropriate motor current. Alternatively, a parking switch can activate the brake and an inclination sensor can provide a motor current level more than adequate for the grade, with a fully laden vehicle. With either system (and unlike a spring brake), the motor is controlled to provide enough torque to park the vehicle, without using unnecessarily high torques which load the mechanism excessively. Also, because current is proportional to torque, when the brake is applied for a parking brake application a datum point may be set when a predetermined force level is reached, and this datum point would be utilized by the controller during the release of the brake. Brake release would be accomplished by reversing the motor, but in order to maintain proper brake adjustment, the motor should be stopped when a small brake pad clearance is reached. To do this, the motor controller senses a predetermined low level current at the datum, during backoff, then continues turning the motor for a desired number of motor turns, which creates the necessary pad clearance.

Drive shaft flat 42 (see Figures 1 and 6) permits the attachment of a hand crank so that the brake can be applied or released manually.

Turning now to Figure 6, there is illustrated an electrically operated disc brake 110 which utilizes an electric motor for both service and parking brake applications. Similar structure will be indicated by the same numerals utilized above. The caliper housing 114 includes a stepped bore 116, the stepped bore having a radially extending wall 118 which extends to an opening 119 that provides journalling for the output shaft of the electric motor 40. The planetary gear system 150 includes a fixed

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ring gear 70 and a rotatable ring gear 180. The rotatable ring gear 180 has fewer teeth than the fixed ring gear 70. Rotatable ring gear 180 includes a seal 84 disposed thereabout and gear 180 engages a ring 85 extending radially inwardly of stepped bore 116. Piston 130 is disposed at the entrance of stepped bore 116 and is positioned on rotatable ring gear 180. Another seal 184 is disposed about rotatable ring gear 180 and engages the interior surface of opening 131 of piston 130. Rotatable ring gear 180 engages screw means 188 by means of internal ring gear threads 185 and screw means threads 189. Screw means 188 is fixed nonrotatably through a key connection 190 with piston 130. Piston 130 is fixed nonrotatably by a key connection 192 with the inner friction element 118. In this embodiment of the invention, the rotatable ring gear 180 engages directly screw means 188 which is fixed nonrotatably with the piston that is fixed to the nonrotatable friction element 118. Thus, as rotatable ring gear 180 rotates, screw means 188 is displaced axially to engage friction element 118 with rotor 22, and by reaction, friction element 120 with the other side of rotor 22. The caliper housing 114 has an extension 124 which houses the electric motor 40. Because rotatable ring 180 engages directly screw means 188 which is fixed nonrotatably to piston 130, that portion of the structure is substantially shortened axially in relation to the previous embodiment. This enables electric motor 40 to be housed directly within extension 124 of caliper housing 114, the overall length of electric brake 110 being shortened. Electrically operated disc brake 110 has a planetary gear system which operates identically to that described above, but does not utilize any hydraulic pressure to actuate piston 130. Piston 130 is actuated both for service brake and parking brake applications by electric motor 40. In all other respects, electric disc brake 110 operates as described above for the first embodiment. Figure 7 illustrates an alternative piston-screw means-rotatable ring gear structure. Screw means



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288 is connected nonrotatably by spline connection 286 with rotatable ring gear 280, and screw means threads 289 engage piston threads 285 of piston 230.

5 The disc brake of Figure 6 may be utilized for a parking brake application and a separate hydraulic disc brake utilized for service brake applications. Figure 8 illustrates a duplex support plate 300 which supports both the electric disc brake 110 and a separate hydraulically operated disc brake 400 (both shown in dotted line  
10 outlines).

Figure 9 illustrates a twin bore disc brake 310 having a pair of disc brake mechanisms disposed within twin bores and actuated by an electric motor disposed adjacent or parallel to the bores of the actuators. Twin  
15 bore disc brake 310 includes a caliper 312 which engages outer friction element 320, caliper housing 314 having bores 316 receiving therein pistons 330. Each piston 330 is displaced either by pressurized hydraulic brake fluid or by the electric motor 340 via the planetary gear  
20 assembly 350. Each piston 330 engages the inner brake pad 318 disposed adjacent rotor 322, piston 330 receiving nonrotatably by means of a key connection the nut 390 engaging the screw means 388. Piston 330 engages nonrotatably by means of key connection 393 the friction  
25 element 318. Each planetary gear assembly 350 is identical to those described above, in that it includes a nonrotatable ring gear 370 disposed coaxially with the rotatable ring gear 380, the gear assembly 350 including a sun gear 352 which drives three planetary gears. Sun  
30 gear 352 is connected with gear 351 that is engaged by idler 353 (see Figure 10). The electric motor 340 is disposed parallel to the axis of bore 316, and includes a drive shaft 341 with drive gear 345 that powers idler 353. Idler 353 drives the two gears 351 each of which is  
35 connected via a shaft with an associated sun gear. Figure 10 illustrates an end section view of the disc brake 310, and each bore of the twin bore disc brake

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includes a planetary gear assembly 350 and other structure identical to that shown in Figure 9. Disc brake 310 includes an outer end plastic housing cover 317 which is held in place by clamp bracket 321 (see Figure 11).  
5 Clamp bracket 321 includes legs 323 which hold housing cover 317 in place. As shown by Figure 9, caliper housing 314 includes end portion 315 which is integral with the remaining portions of caliper housing 314 so that the planetary gear assemblies 350 and pistons 330 are both  
10 enclosed within the bores 316. The outer diameter of the planetary gear assemblies 350 located within the twin bores of disc brake 310 are essentially the same as the outer piston diameters. Thus, the gear assemblies 350 are small enough to be housed within bores 316 and provide the required actuation loads while permitting the  
15 utilization of an integral caliper housing which is disposed about the ends of gear assemblies 350 in order to receive the reaction loading or forces effected by assemblies 350 when they operate and displace pistons 330  
20 outwardly against rotor 322.

Figures 12 and 13 represent an embodiment which comprises a twin bore disc brake 410 having one piston actuated solely by means of hydraulic fluid pressure and the other piston actuated by either hydraulic fluid pressure or by means of a planetary gear assembly 450 actuated by an electric motor 440 disposed parallel to the twin bores. Structure similar to that described above is identified by the same numeral increased by 100. Disc brake 410 comprises a right side bore 416 housing the  
25 piston 430, screw means 488, nut 490, and planetary gear assembly 450. The left side bore 428 (see Figure 13) includes a typical disc brake piston (not shown) which is actuated or displaced solely by pressurized brake fluid. The electric motor 440 is disposed upon an axis located  
30 parallel to the longitudinal axis of disc brake 410, and includes a motor shaft 441 connected to a drive gear 445 which drives the idler 453 that engages gear 451 connected with sun gear 452. As a result, the left side  
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bore 428 (see Figure 13) containing the hydraulically actuated piston may be utilized for service brake applications, while the right side bore 416 containing the planetary gear assembly 450 may be actuated by electric motor 440 via idler 453 for parking brake applications and actuated hydraulically for service brake applications.

The various embodiments of the disc brake having the planetary gear assembly may be utilized for drive line braking of a vehicle. The "rotor" to be braked may be attached to the vehicle's propulsion shaft or driven by it, and the caliper mounted on the transmission or rear axle assembly. All of the above-described motors may be electric motors, hydraulic motors, and any other appropriate driving source.

Other provisions of the invention or variations will become apparent to those skilled in the art and will suggest themselves from the specific applications of the invention. It is intended that such variations and revisions of the invention as reasonably to be expected on the part of those skilled in the art, to suit individual design preference and which incorporate the herein disclosed principles, will be included within the scope of the following claims as equivalents thereof.

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-10-

## CLAIMS:

1. A disc brake that may be operated by electric motor means, comprising a caliper (12, 312, 412) having a bore (16, 26, 116, 316, 416) with a piston (30, 130, 230, 330, 430) slidably received therein, the caliper (12, 312, 412) and piston (30, 130, 230, 330, 430) actuable to displace a pair of friction elements (18, 20; 118, 120; 318, 320; 418, 420) into engagement with a rotor (22, 322, 422), and means for operating the piston, characterized in that the operating means comprises a planetary gear assembly (50, 150, 350, 450) disposed within said bore (16, 26, 116, 316, 416) and comprising a sun gear (52, 352, 452), a carrier (60, 460), planetary gears (54, 56, 58), and a pair of ring gears (70, 370, 470; 80, 180, 280, 380, 480), and the electric motor means (40, 340, 440) coupled with said sun gear (52, 352, 452) which drives the planetary gears (54, 56, 58), one ring gear (70, 370, 470) fixed to said caliper (12, 312, 412) and the other ring gear (80, 180, 280, 380, 480) rotatable by said planetary gears (54, 56, 58), the other ring gear (80, 180, 280, 380, 480) engaging screw means (88, 188, 288, 388, 488) which is connected with said piston (30, 130, 230, 330, 430), operation of said electric motor means (40, 340, 440) causing rotation of said other ring gear (80, 180, 280, 380, 480) and operative displacement of said piston (30, 130, 230, 330, 430) into engagement with one (18, 118, 318, 418) of said friction elements so that the caliper (12, 312, 412), by reaction, displaces the other friction element (20, 120, 320, 420) into engagement with said rotor (22, 322, 422).

2. The disc brake in accordance with claim 1, characterized in that the piston (30, 330, 430) includes sealing means (32, 484) disposed thereabout and the other ring gear (80, 380, 480) includes a pair of seals (84) disposed thereabout, the sealing means (32, 484) and pair of seals (84) effective to retain fluid within a portion of the bore (16, 316, 416) disposed axially between said pair of seals (84) and sealing means (32, 484) so that

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said piston (30, 330, 430) may be operated by hydraulic pressure.

3. The disc brake in accordance with claim 1, characterized in that said other ring gear (86, 280, 380, 480) is coupled fixedly with said screw means (88, 288, 388, 488) in order to effect rotation thereof.

4. The disc brake in accordance with claim 3, characterized in that said piston (30, 330, 430) is connected with said screw means (88, 388, 484) by means of a nut (90, 390, 490) having internal threads engaging threads of the screw means (88, 388, 488).

5. The disc brake in accordance with claim 4, characterized in that the nut (90, 390, 490) and piston (30, 330, 430) are coupled together by a key connection (92, 492) which prevents relative rotation therebetween.

6. The disc brake in accordance with claim 1, characterized in that the brake comprises a screw retaining plate (89) disposed about said screw means (88), the screw retaining plate (89) preventing axial displacement of said screw means (88).

7. The disc brake in accordance with claim 1, characterized in that the brake further comprises a motor plate (100) disposed within a motor housing (24) of the caliper (12) and effecting alignment of said motor means (40).

8. The disc brake in accordance with claim 7, characterized in that the motor plate (100) engages both the bore (26) and the motor means (40) in order to effect positioning of the motor means (40), and extends within the motor housing (24) in order to keep contaminants from entering said planetary gear assembly (50).

9. The disc brake in accordance with claim 1, characterized in that the other ring gear (80, 180, 280, 380, 480) has fewer teeth than the fixed ring gear (70, 370, 470) so that other ring gear (80, 180, 280, 380, 480) rotates at a slower rate than said planetary gears (54, 56, 58) rotate.

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10. The disc brake in accordance with claim 1, characterized in that the bore (116) includes ring means (85) disposed therein and projecting radially inwardly of said bore (116), the ring means (85) providing an axial stop for said other ring gear (180).

11. The disc brake in accordance with claim 1, characterized in that the other ring gear (180) includes an opening with internal threads (185) which engage threads (189) of the screw means (188).

12. The disc brake in accordance with claim 11, characterized in that the screw means (188) is nonrotatably fixed to said piston (130), so that rotation of said other ring gear (180) effects axial displacement of said screw means (188) and piston (130).

13. The disc brake in accordance with claim 12, characterized in that said one friction element (118) and piston (130) are coupled together nonrotatably.

14. The disc brake in accordance with claim 13, characterized in that said other ring gear (180) includes a pair of seals (84, 184) thereabout, one seal (184) engaging an interior surface of an interior bore (131) of said piston (130) and the other seal (84) engaging the bore (116) of the caliper.

15. The disc brake in accordance with claim 1, characterized in that the caliper comprises an integral housing (114) with the bore (116) being a stepped bore (116) that receives at one end the motor means (40).

16. A twin bore disc brake assembly that may be operated by motor means, comprising a caliper (312, 412) having a pair of bores (316, 416, 428) each with a piston (330, 430) slidably received therein, the caliper (312, 412) and pistons (330, 430) actuatable to displace a pair of friction elements (318, 320, 418, 420) into engagement with a rotor (322, 422), a planetary gear assembly (350, 450) disposed within one bore (316, 416) and comprising a sun gear (352, 452), planetary gears (54, 56, 58), and a pair of ring gears (370, 380, 470, 480), the motor means

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(340, 440) disposed adjacent the bores (316, 416) and coupled operatively with said sun gear (352, 452) which drives the planetary gears (54, 56, 58), one ring gear (370, 470) fixed to said caliper (312, 412) and the other ring gear (380, 480) rotatable by said planetary gears (54, 56, 58), the other ring gear (380, 480) engaging screw means (388, 488) which is connected with one (330, 430) of the pistons, the other bore (316, 428) having the other of said pistons (330, 430), operation of said motor means (340, 440) causing rotation of said other ring gear (380, 480) and operative displacement of at least said one piston (330, 430) into engagement with one (318, 418) of said friction elements (318, 320; 418, 420) so that the caliper (312, 412), by reaction, displaces the other friction element (320, 420) into engagement with said rotor (322, 422).

17. The twin bore disc brake assembly in accordance with claim 16, characterized in that each bore (316) includes a planetary gear assembly (350), and operation of the motor means (340) causes operative displacement of both of said pistons (330) into engagement with said one (318) of the friction elements (318, 320).

18. The twin bore disc brake assembly in accordance with claim 17, characterized in that said caliper (312) includes integral end portions (315) about each of said bores (316), the end portions (315) enclosing ends of the bores (316) and positioning said planetary gear assemblies (350).

19. The twin bore disc brake assembly in accordance with claim 18, characterized in that the caliper (312) has an exterior cover (317) disposed over an end of the caliper (312), the cover (317) held in place by a clamp band (321).

20. The twin bore disc brake assembly in accordance with claim 19, characterized in that the clamp band (321) includes a pair of legs (323) which extend over said cover (317) and engage portions of the caliper (312).

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21. The twin bore disc brake assembly in accordance with claim 16, wherein the other (316, 428) of the bores (316, 416, 428) includes a piston (330) displaceable by pressurized fluid, and the planetary gear assembly (350, 450) disposed within the one bore (316, 416) actuable by the motor means (340, 440).

22. The twin bore disc brake assembly in accordance with claim 21, characterized in that the motor (440) is electric and is connected with the sun gear (452) by means of an idler gear (453) and a gear (451) operatively connected with the sun gear.

23. The twin bore disc brake assembly in accordance with claim 16, characterized in that the other (428) of the bores (416, 428) includes a piston displaceable solely by pressurized fluid.

24. The twin bore disc brake assembly in accordance with claim 16, characterized in that each of the pistons (330) is displaceable by pressurized fluid.



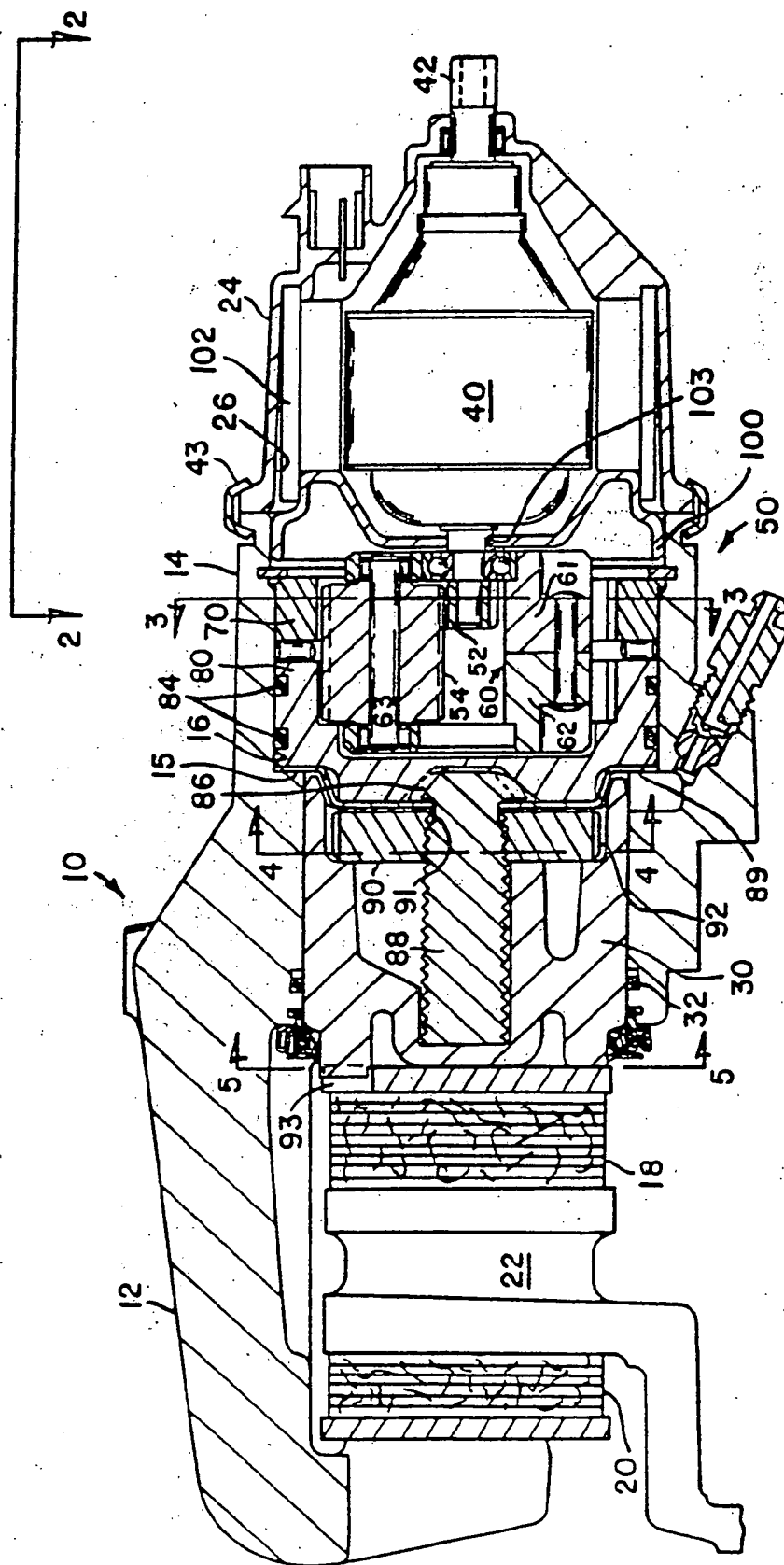
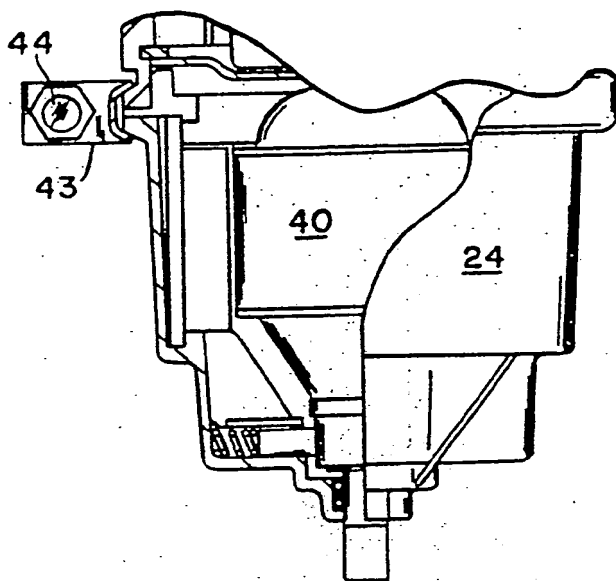
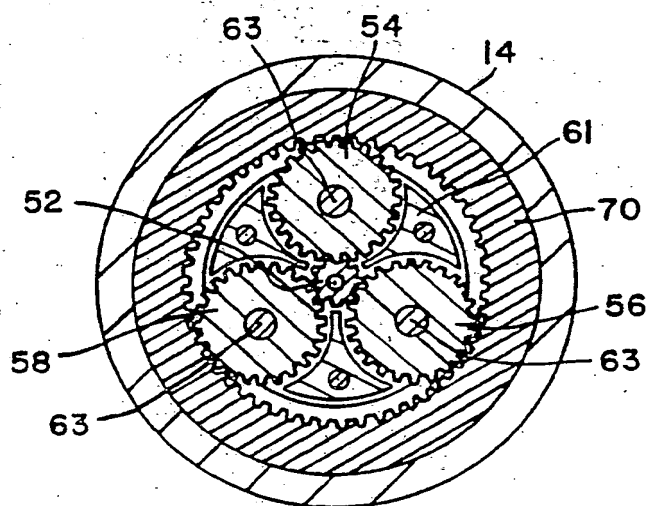


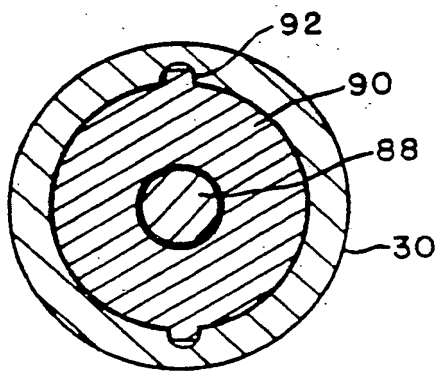
FIG. 1



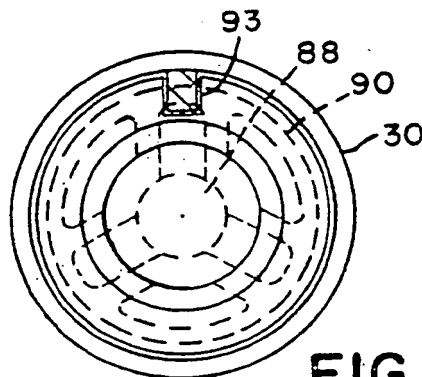
**FIG. 2**



**FIG. 3**



**FIG. 4**



**FIG. 5**

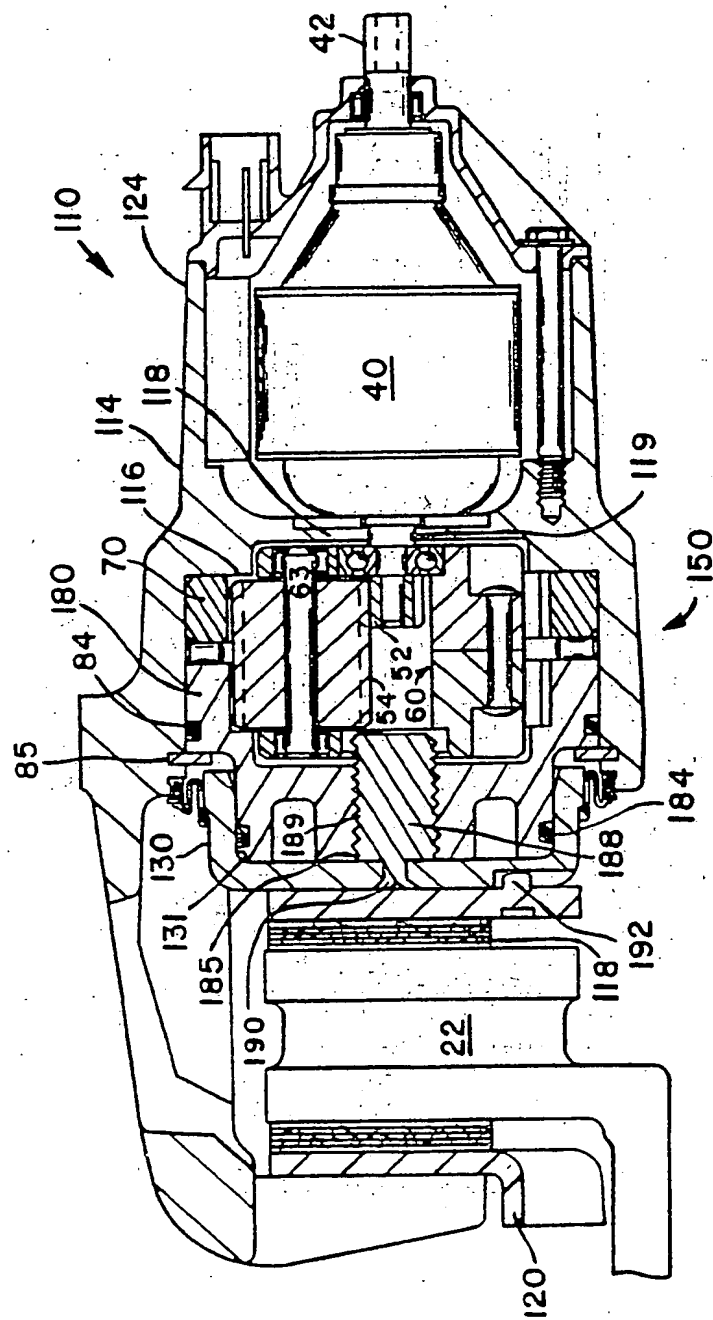


FIG. 6

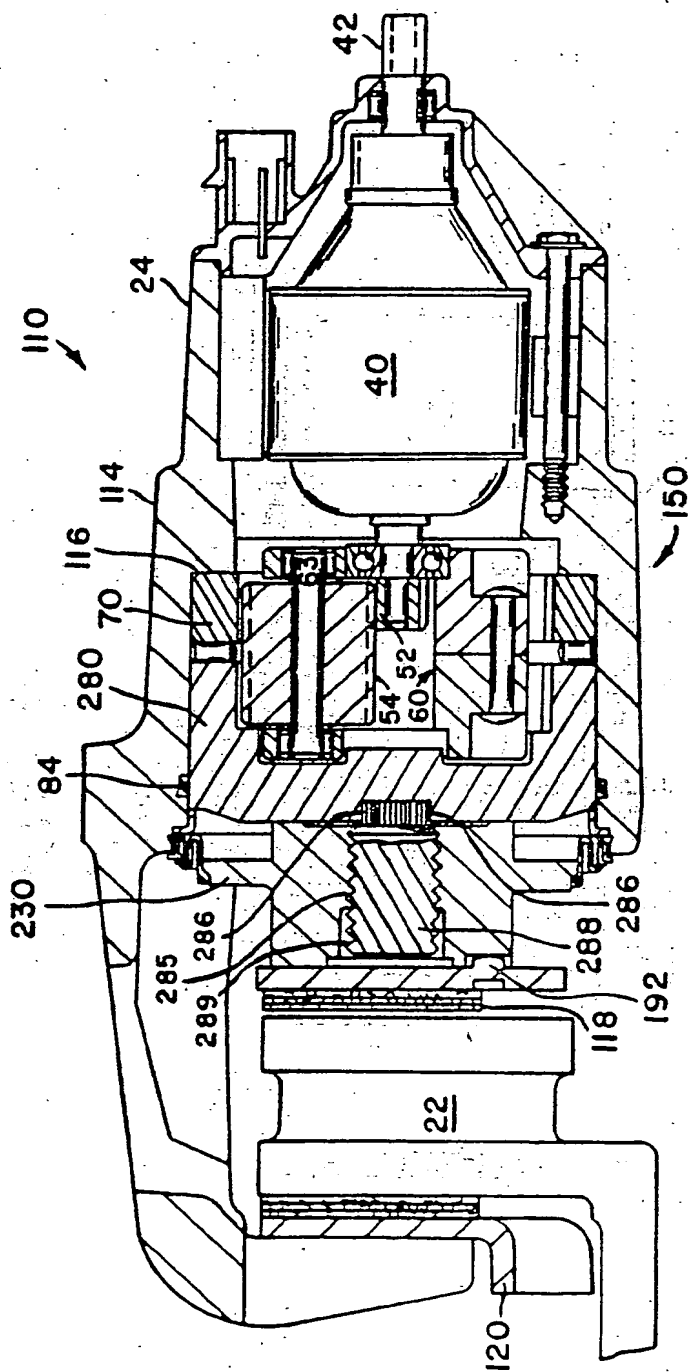


FIG. 7

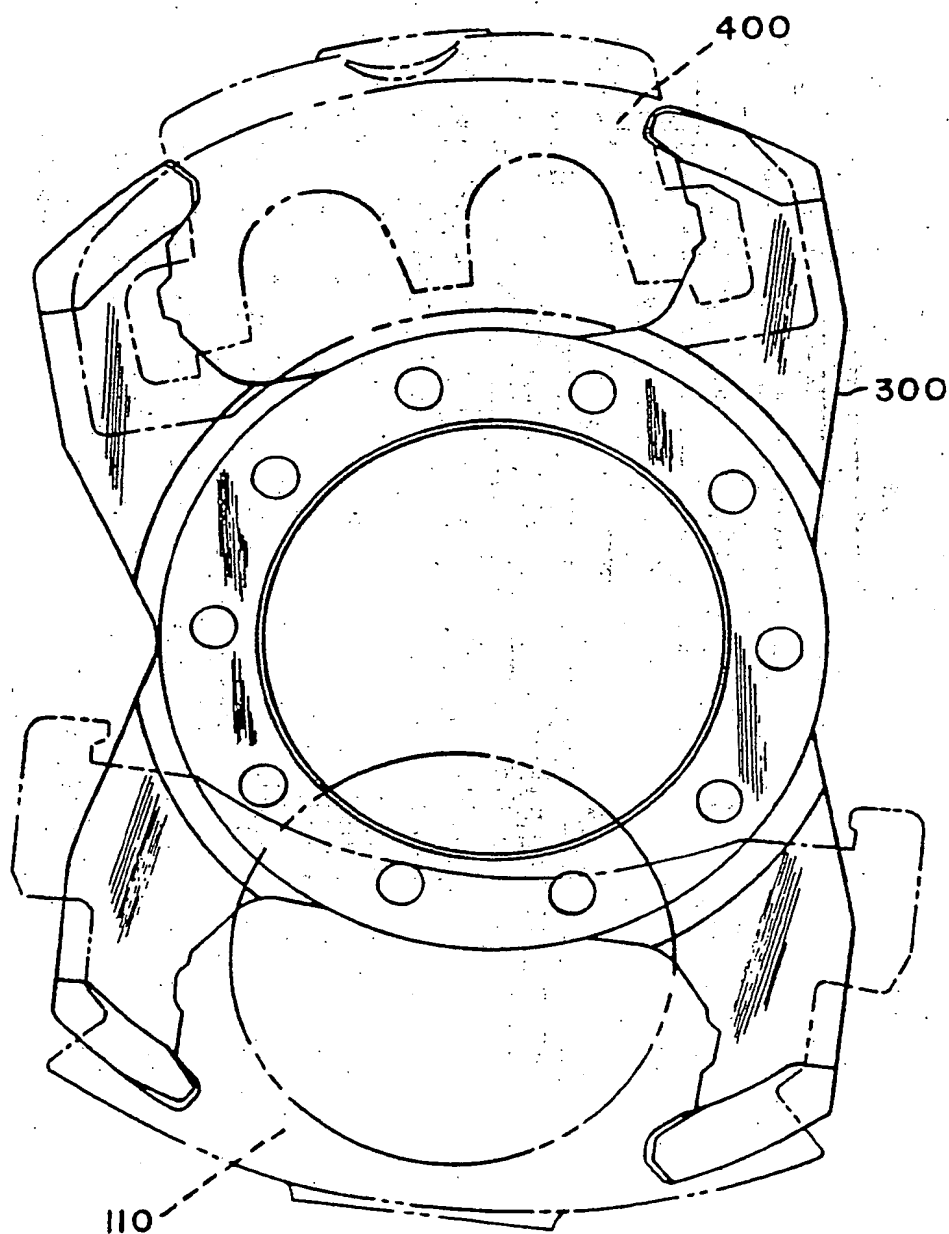


FIG. 8

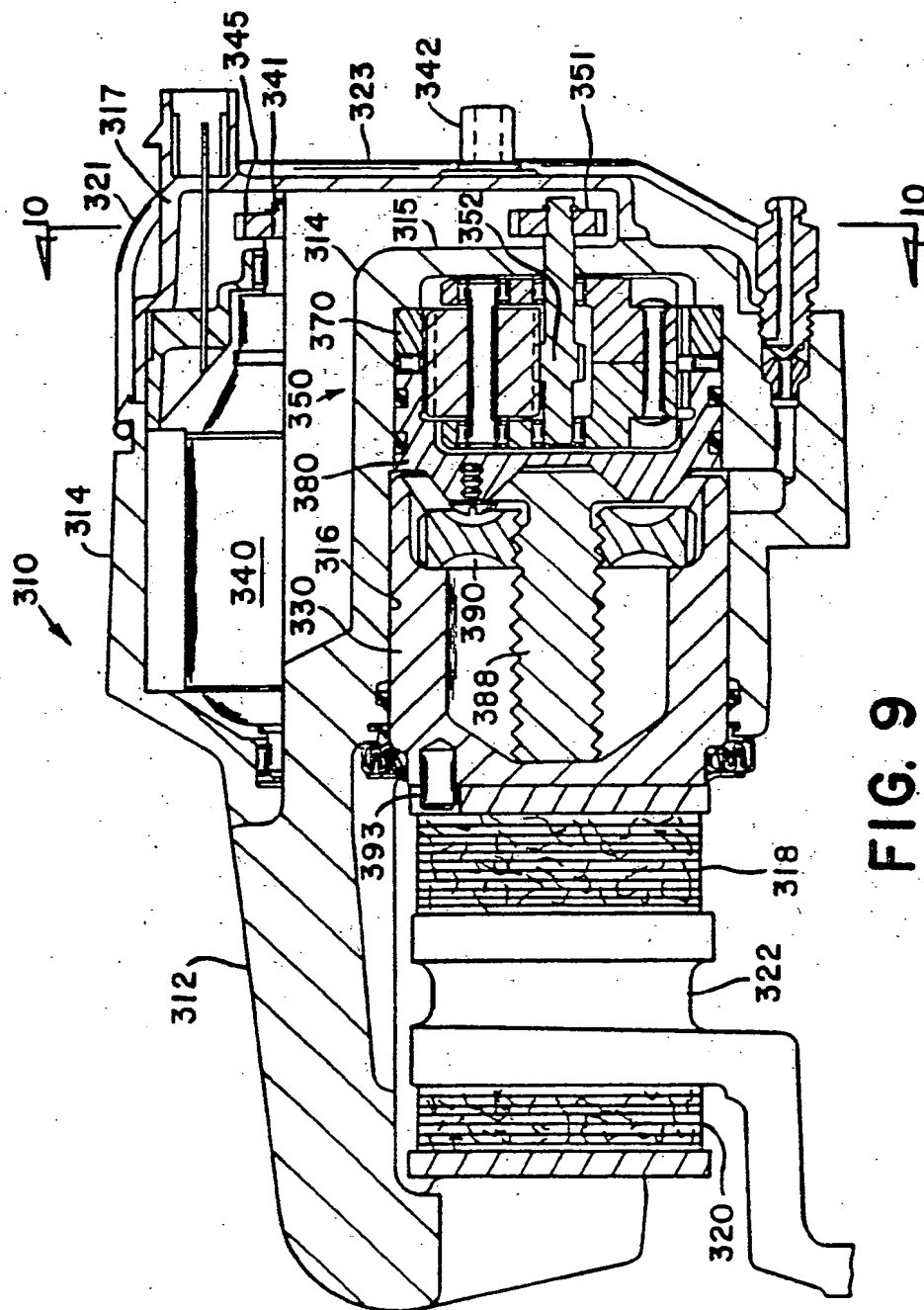


FIG. 9

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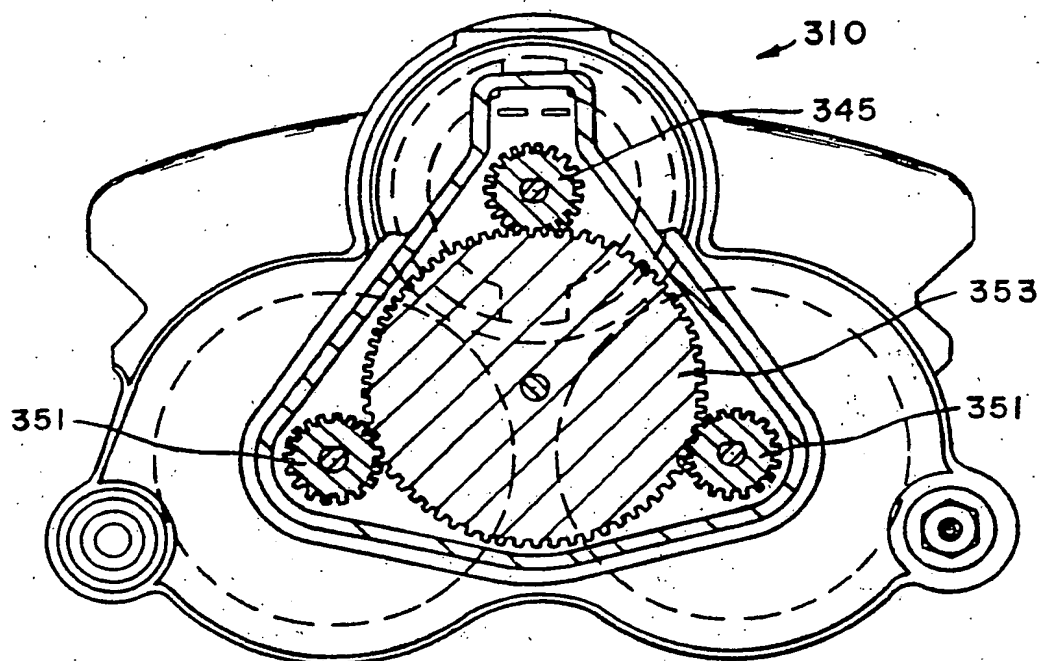


FIG. 10

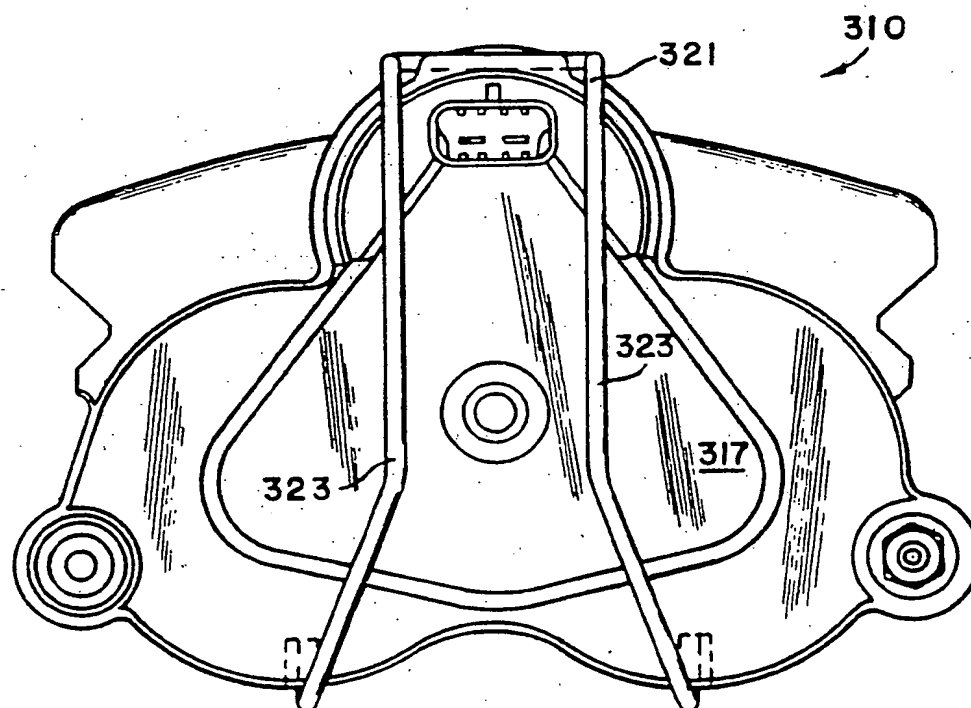


FIG. 11

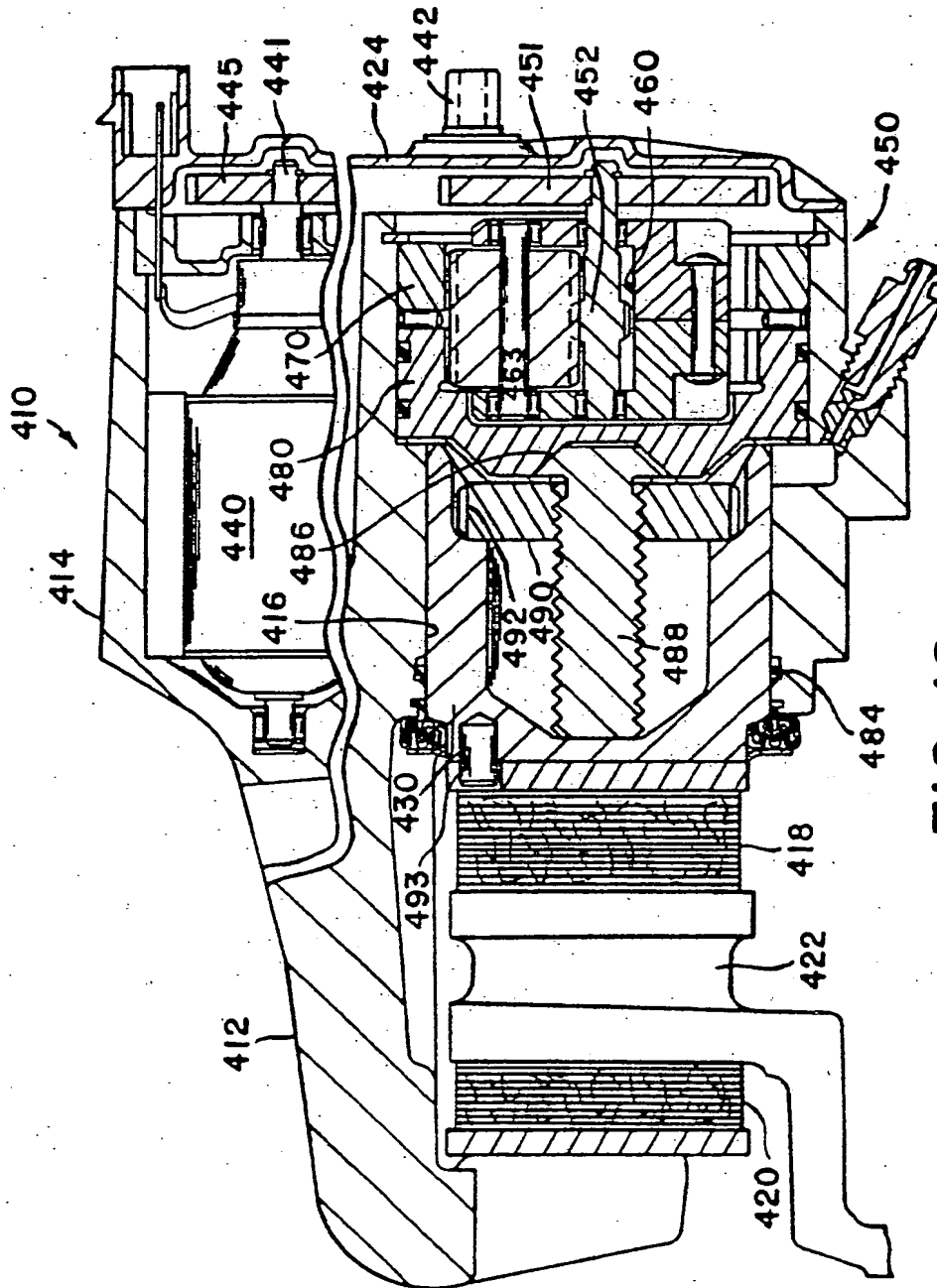


FIG. 12



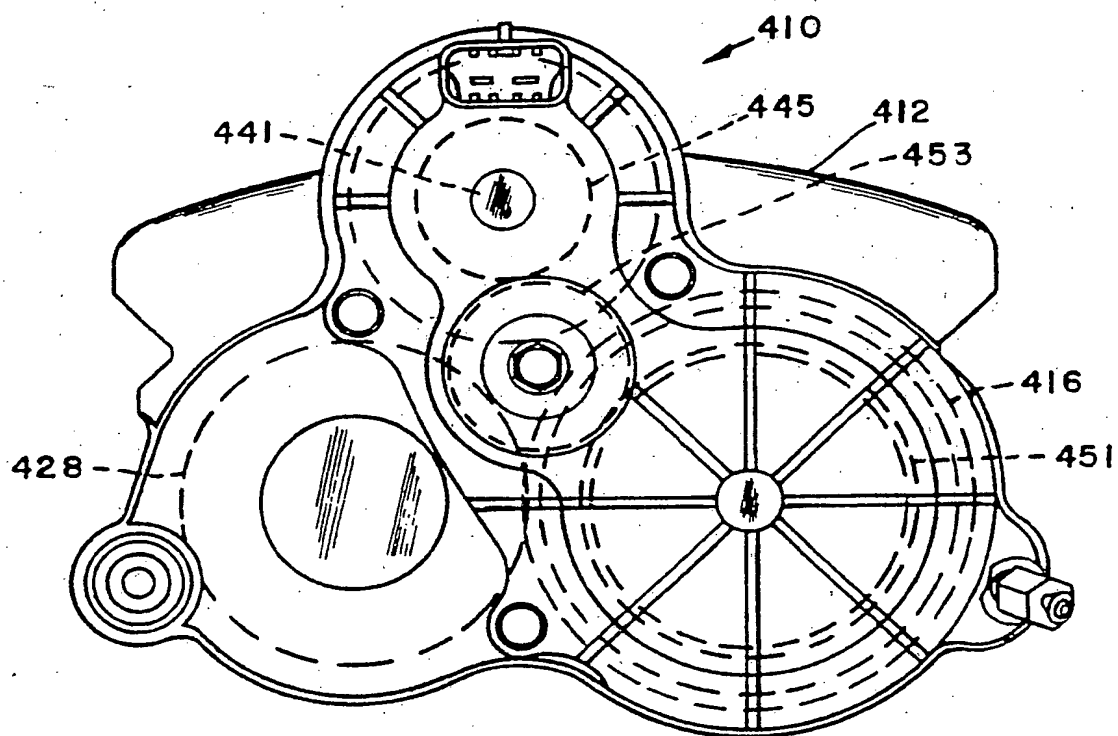
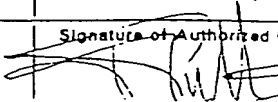
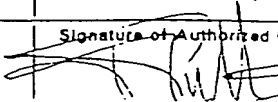
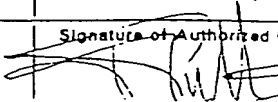


FIG. 13

# INTERNATIONAL SEARCH REPORT

International Application No PCT/US 87/02348

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup> According to International Patent Classification (IPC) or to both National Classification and IPC IPC <sup>4</sup> : F 16 D 65/16; F 16 D 63/00; B 60 T 13/74; F 16 D 55/224														
<b>II. FIELDS SEARCHED</b> <div style="text-align: center; margin-top: 10px;">Minimum Documentation Searched <sup>7</sup></div> <table style="width: 100%; border: none;"> <tr> <td style="width: 25%; border: none;">Classification System  </td> <td style="border: none;">Classification Symbols</td> </tr> <tr> <td style="border: none; vertical-align: top;">IPC<sup>4</sup></td> <td style="border: none; vertical-align: top;">F 16 D 65/00, F 16 D 63/00; B 60 T 13/00; F 16 D 55/00</td> </tr> </table> <div style="text-align: center; margin-top: 10px; font-size: small;">Documentation Searched other than Minimum Documentation to the extent that such Documents are Included in the Fields Searched <sup>8</sup></div>			Classification System	Classification Symbols	IPC <sup>4</sup>	F 16 D 65/00, F 16 D 63/00; B 60 T 13/00; F 16 D 55/00								
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IPC <sup>4</sup>	F 16 D 65/00, F 16 D 63/00; B 60 T 13/00; F 16 D 55/00													
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup></b> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%; text-align: left; padding: 5px;">Category <sup>*</sup></th> <th style="width: 70%; text-align: left; padding: 5px;">Citation of Document, <sup>11</sup> with Indication, where appropriate, of the relevant passages <sup>12</sup></th> <th style="width: 20%; text-align: left; padding: 5px;">Relevant to Claim No. <sup>13</sup></th> </tr> </thead> <tbody> <tr> <td style="vertical-align: top; padding: 5px;">A</td> <td style="vertical-align: top; padding: 5px;">GB, A, 2156021 (ALFRED TEVES GmbH) 2 October 1985 see the whole document, figures 1-3</td> <td style="vertical-align: top; padding: 5px;">1, 2</td> </tr> <tr> <td style="vertical-align: top; padding: 5px;">A</td> <td style="vertical-align: top; padding: 5px;">EP, A, 0129969 (WESTINGHOUSE BRAKE AND SIGNAL CO. LTD) 2 January 1985 see page 24, line 31 - page 25, line 35; figure 5</td> <td style="vertical-align: top; padding: 5px;">1</td> </tr> <tr> <td colspan="3" style="height: 150px;"></td> </tr> </tbody> </table>			Category <sup>*</sup>	Citation of Document, <sup>11</sup> with Indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>	A	GB, A, 2156021 (ALFRED TEVES GmbH) 2 October 1985 see the whole document, figures 1-3	1, 2	A	EP, A, 0129969 (WESTINGHOUSE BRAKE AND SIGNAL CO. LTD) 2 January 1985 see page 24, line 31 - page 25, line 35; figure 5	1			
Category <sup>*</sup>	Citation of Document, <sup>11</sup> with Indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>												
A	GB, A, 2156021 (ALFRED TEVES GmbH) 2 October 1985 see the whole document, figures 1-3	1, 2												
A	EP, A, 0129969 (WESTINGHOUSE BRAKE AND SIGNAL CO. LTD) 2 January 1985 see page 24, line 31 - page 25, line 35; figure 5	1												
<div style="display: flex; justify-content: space-between; font-size: x-small;"> <div style="width: 45%;"> <p><sup>*</sup> Special categories of cited documents: <sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p> </div> </div>														
<b>IV. CERTIFICATION</b> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;">           Date of the Actual Completion of the International Search            8th January 1988         </td> <td style="width: 50%; border: none; vertical-align: top;">           Date of Mailing of this International Search Report            17 FEB 1988         </td> </tr> <tr> <td style="border: none; vertical-align: top;">           International Searching Authority            EUROPEAN PATENT OFFICE         </td> <td style="border: none; vertical-align: top;">           Signature of Authorized Officer  <div style="text-align: center;">               P.C.G. VAN DER PUTTEN           </div> </td> </tr> </table>			Date of the Actual Completion of the International Search 8th January 1988	Date of Mailing of this International Search Report 17 FEB 1988	International Searching Authority EUROPEAN PATENT OFFICE	Signature of Authorized Officer <div style="text-align: center;">               P.C.G. VAN DER PUTTEN           </div>								
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International Searching Authority EUROPEAN PATENT OFFICE	Signature of Authorized Officer <div style="text-align: center;">               P.C.G. VAN DER PUTTEN           </div>													

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.**

US 8702348  
SA 19064

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 29/01/88. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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